Design of Mobile Emergency Telemedicine System Based on CDMA2000 1X-EVDO

Seok Myung Jung[a], Sun K. Yoo[b], Kim[c], Hayoung Yun[d], Sungrim Kim[e]

[a] *Ph D. Candidate, Department of Medical Engineering, College of Medicine, Yonsei University, Korea*
[b] *Professor, Department of Medical Engineering, College of Medicine, Yonsei University, Seoul, Korea*
[c] *M. S. Candidate, Department of Medical Engineering, College of Medicine, Yonsei University, Korea*
[d] *Undergraduate, College of Electrical and Electronic Engineering, Yonsei University, Seoul, Korea*
[e] *Instructor, Department of Computer Science, College of Computer & Information Science Dongduk Womem's University, Seoul, Korea*

Abstract

The medical service with a high data rate can be supported in mobile emergency telemedicine system by development of cellular communications networks. In Korea, the commercial service of CDMA2000 1X-EVDO is provided since 2002.

In this paper, we designed the system that transfers biological signal and video signal information of patients simultaneously based on this communication network environment. In CDMA2000 1X-EVDO, the maximum backward speed is observed to be 153.6Kbps. Several field tests are performed using commercial CDMA2000 1X-EVDO to realize the emergency telemedicine system fitted to feature of CDMA2000 1X-EVDO.

With the designed system, we could transmit biological signals and MPEG4 images of spatial resolution 640x480 simultaneously. We set up the system in an ambulance and tested it on the road.

Keywords: emergency telemedicine; CDMA2000 1X-EVDO; ARQ

Introduction

The mobile emergency telemedicine system is the new research area that support medical care with high data rate based on cellular telecommunication networks that has been developed [1,2].

With the change of the generation of telecommunication, there has been a continuous development on the research of using cellular communication for the ambulance for which emergency is the most important factor of its transportation [3, 4].

In Korea, third generation mobile telecommunication system, CDMA2000 1X-EVDO (Evolution-Data Only) was commercialized since 2002. This is a protocol for the transmission of packet data differ entirely from existing IS-2000 wireless protocol. CDMA2000 1X-EVDO has asymmetric data rate structure that has the maximum forward speed as 2.4576Mbps and the maximum backward speed as 153.6Kbps. Also IS-2000 wireless protocol supports the wireless section transmission speed of 153.6Kbps, but as to business part the maximum speed as 64Kbps is allocated to wireless internet because of the capacity problem of the section. And basically IS-2000 wireless protocol is sensitive to the delay of voice activity rate. However CDMA2000 1X-EVDO allocates the speed of users actively in the wireless section and maximize the using efficiency of the system. The wireless section by using maximally dormant mode is the feature of packet data.

The purpose of this research is to design medical care system that can transmit multimedia data during movement by using the backward channel feature of CDMA2000 1X-EVDO [5]. The information transmitted to the emergency room are ECG (Electrocardiogram), SpO2, NIBP(Non invasive Blood Pressure), respiration, and simultaneous video signal information that is useful to diagnosis the patients of an external injury.

From the field test, we analyzed the movement speed and the features of CDMA2000 1X-EVDO. Based on the result, we determined the transmission way to improve the system efficiency and applied it in the ambulance.

The backward channel of 1X-EVDO

In CDMA2000 1X-EVDO, the transmissions are controlled by RLP(Radio Link Protocol) 3 version. Figure 1 shows the equipments of the designed system and the network structure. The data transmitted at transmission speed of 153.6Kbps through reverse link from an ambulance connects to IP network through PDSN in base station, and they are transmitted to emergency center receiver.

We performed several field tests with the commercial CDMA2000 1X-EVDO in order to realize emergency telemedicine system fitted to the backward feature of CDMA2000 1X-EVDO. By using UDP (User Datagram Protocol) packet, we measured the transmitted state of 1MB data in the receiver with the changing movement speed of the ambulance. Then we measured P_E(Error Probability) according to loss of packet data and transmission speed of the data.

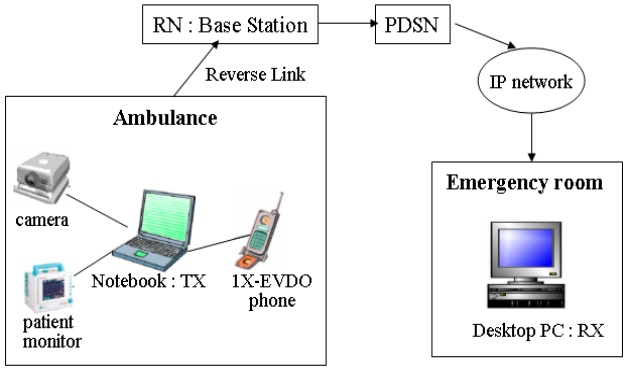

Figure 1. The Emergency Telemedicine System in CDMA2000 1X-EVDO

System Design

We designed a special transmission mode to transmit effectively using on the CDMA2000 1X-EVDO field test results. UDP is connection-less, therefore it is profitable for streaming service [6].

First, we need additional header information to apply UDP protocol effectively to the emergency telemedicine system.

Concerning mobile network's special characteristics, we append a special header to transmit biological signal and video signal information efficiently without using RTP [7]. Figure 2 shows transmission data structure that was devised to transmit using UDP protocol.

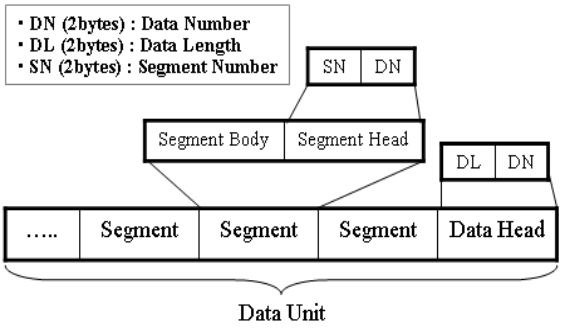

Figure 2. Transmission Data Structure

Data Unit is standard unit that processes biological signal and video signal in telemedicine system. Segment unit is real data unit that transmitted by the UDP protocol. DN(Data Number) distinguishes the kind of data by using an odd number when it is video signal information and an even number when it is biological signal. Because UDP protocol does not secure transmission order, we included order information at Data Unit and Segment.

Figure 3 shows the mobile emergency telemedicine system. It is consisted of two parts : transmits emergency patient's biological signal and video signal information that is transferred in ambulance in real time to emergency center through CDMA2000 1X-EVDO, and displays transmitted data in emergency center.

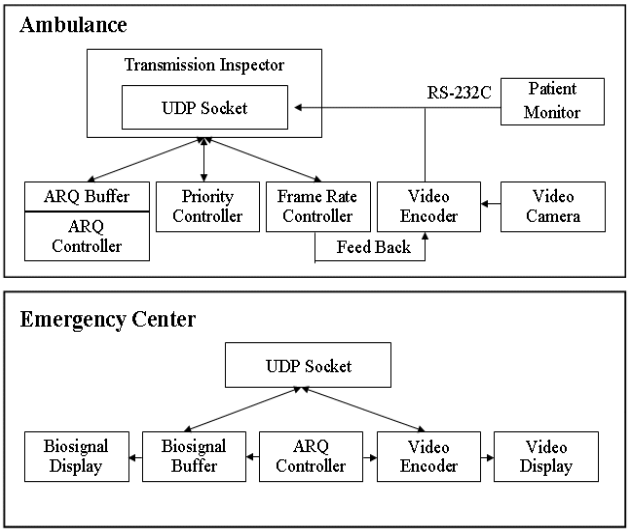

Figure 3. Mobile Emergency Telemedicine System

Transmitting system is consists of data's input part, transmission control part, and UDP transmission part. Biological signal is measured by patient monitor and is inputted to the notebook through RS-232C interface. Analog video signal is compressed by MPEG4 format (spatial resolution 640x480) being inputted through video camera. This is stored in the buffer of ARQ Controller inner parts for schedule period after being transmitted by UDP via Transmission Inspector. This is for responding to ARQ. Therefore this retransmits stored data when retransmission needs a part that is not transmitted through RLP in CDMA2000 1X-EVDO layer during transmission process.

The buffer of the receiving system checks packet's sequence number and awareness header preferentially. Buffer considering ARQ timing, and apply ARQ during schedule delay time (2 seconds) for real time display when it requires transmitter's re-transmission through ARQ about packet with errors. Transmitter's ARQ Buffer stores data temporarily.

We control transmitted data at transmitter and receiver to adapt to variable wireless network according to time and speed. To control transmission data, we used priority control, frame rate control and error control.

- Priority control : There are many cases in biological signal that is very important in emergency patient's diagnosis [1]. We put Priority Controller to secure transmission of biological signal preferentially than video signal. Priority Controller operates when bandwidth approximate to minimum biological signal bandwidth, 8Kbps. Priority Controller regulates by these modes so that biological signal of the schedule amount may be transmitted.
- Frame rate control : Transmitter controls video frame rate according to the buffer state of the transmission socket. Before entering in continuous low bandwidth, Frame Rate Controller drops frame rate first. After entering, Priority Controller almost intercepts video signal transmission and offers priority to biological signal transmission.
- Error control : Receiver handles error occurrence using ARQ. Receiver examines data head and stores sequentially

to the receiving buffer.

If the received packet is lost, receiver's ARQ Controller sends ARQ signal that request re-transmission in transmission of a message decision. If transmitter receives ARQ signal from receiver, it brings and transmits again relevant data in ARQ Buffer. According to lost data, video signal handles 1 time and biological signal processes ARQ signal to 2 times. This serves to secure transmission of biological signal more preferentially than video signal.

Experiments and Results

The average values of the data are calculated out of the test measured in each morning, afternoon, and evening. And the experiments have been done for 20 times in the place of where it is near the base station and where lots of hand-off are occurring.

We measured speed of vehicle and P_E with adding tunnel environment along with speed change. Also, we measured transmission bit rate with 1 MB data in moving vehicles.

Figure 4 shows the calculated average bit rate of twenty repeated experiments. Transmission speed is 132Kbps in suspension state and it is similar value almost with theoretical transmission speed 153.6Kbps of CDMA2000 1X-EVDO. As the speed of vehicles increases, the transmission speed decreased gradually. But the speed higher than 100Kbps was always guaranteed. There were three tunnels and the length of each tunnel was less than 1km. The transmission speed dropped below than 100Kbps in the tunnel.

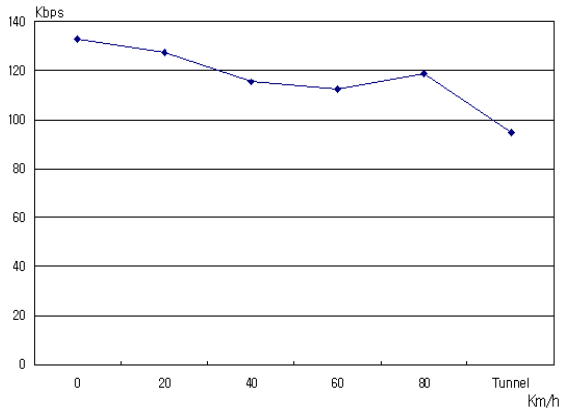

Figure 4. Transmission Rate

Figure 5 displays the change of the bit rate transmission time with each speed. When the connection state is good, bit rate is higher than 140Kbps independently regardless of the change of the speed.

The part that the speed decreases rapidly, by the reason of being flowing in burst error, appears frequently and extensively with the increases of the speed.

In tunnel environment, the decrease of the speed occurred extremely during many long hours, the marked area in Figure 5(f). Specially, when the speed reaches 80km/h, lost data occurred instantaneously, the marked area in Figure 5(e). Thus, we can know that if it is more than the schedule speed or if it passes some obstacle such as tunnel, it is necessary to use ARQ in receiver's buffer to cope with this transmission obstacle.

Figure 6 displays error probability according to the speed of vehicle. This error probability is lost packet's error probability when error is corrected by RLP layer without using ARQ in receiver. In case the speed reaches 80km/h, the error rate increases rapidly, agreeing with the box indicated part of Figure 5(e). On the other hand, there were scarce errors when the speed is 60km/h. This means that RLP layer's special quality that offer in CDMA2000 1X-EVDO covers up to the speed near 80km/h.

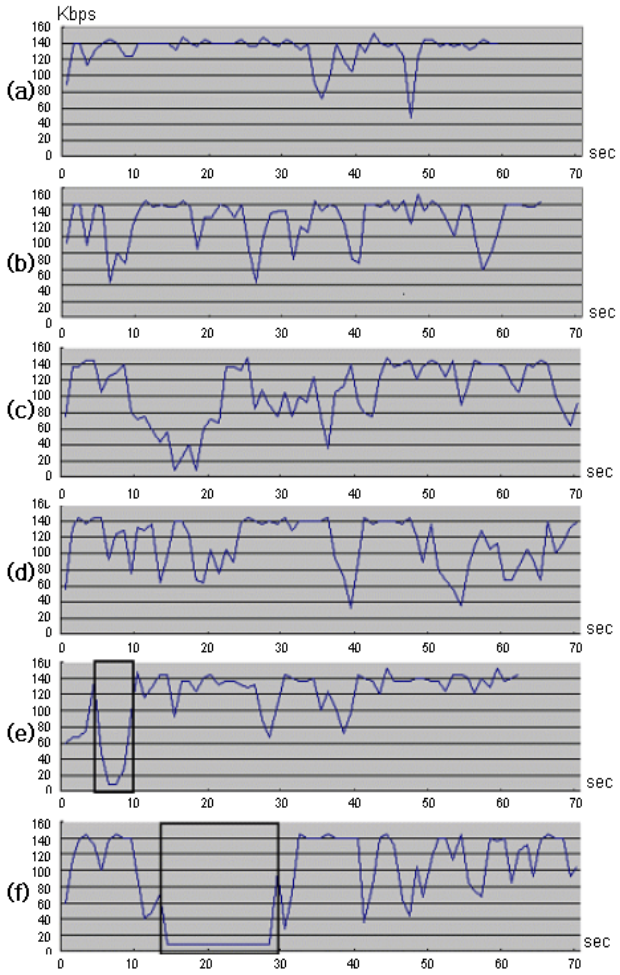

Figure 5. Transmission Patterns

(a) stop (b) 20km/h (c) 40km/h (d) 60km/h (e) 80km/h (f) tunnel

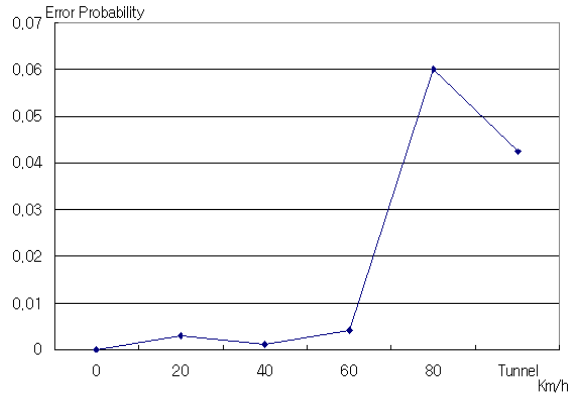

Figure 6. Error Probability

Figure 7 is the picture in the ambulance and Figure 8 is the picture that displays in the emergency center in case patient's biological signal and video signal of facial part is transmitted.

Figure 7. Ambulance

Figure 8. Emergency Center

The followings are the result that observed in moving vehicle.

(a) Biological signal was transmitted with time delay of average of 2.5 seconds. Time delay of video signal information was average of 3 seconds.

(b) Video signal was played 0.5 ~ 5 frames per second (average 2.5 frames per minute).

(c) When the ambulance has stopped, the biological signal has been continuously transmitted, and the video signal has stopped every once a minute (stop duration is 1 second in average)

(d) In the speed from 20 (km/h) to 60 (km/h), biological signal was continuously transmitted, and video signal suspended 3 times per minute (stop duration is 1.5 seconds in average).

(e) Ephemeral delay (4 ~ 5 seconds) occurred in biological signal and video signal transmission in moving situation faster than 80 (km/h) and being in the tunnel (average 3 times per minute) . Obstacle returned again after 2 ~ 3 seconds when the speed was decelerated or ambulance got out of tunnel.

(f) When ambulance shakes because of corner or road surface regardless of speed or tunnel, frame rate of video signal drops by lower than 1 (frame/sec) or suspends after 3 ~ 4 seconds happened.

The reason why there are more stoppages of video signals in case of d) than those of c) can be explained that when the Priority Controller starts operating, it intercepts the video signal in the section of low bandwidth.

In the case of (e) and in case obstacle section is prolonged relatively, transmission rate exceeds frame rate control and priority control's limit, and receiver's ARQ Controller exceeds attempt number of times. In case of (f) we can link with phenomenon that output bit rate increases when motion is increased in MPEG4 encoding of variable bit rate way [8]. In this case, Frame Controller generates the sign that drop frame rate.

Discussion and Conclusion

In this research, we designed a mobile emergency telemedicine system that transmits the biological signal and the video signal of the patient simultaneously by using CDMA2000 1X-EVDO, third generation telecommunication network that has been provided commercially in Korea. In CDMA2000 1X-EVDO, reverse link was proved to maintain the average transmission rate of over 100Kbps. By using this bandwidth, we designed the system that can transmit multimedia data and biological signal simultaneously. For this, we prescribed the limit and the efficiency of the system by measuring error probability and bit rate according to the change of movement speed.

CDMA2000 1X-EVDO shows the feature of variable bandwidth. Therefore, we implemented the control parts to guarantee QoS of transmission data of emergency medical care. In the transmitter we applied frame rate control and priority control, and in the receiver we applied ARQ that is differential to the receiving data.

Acknowledgments

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Address for Correspondence

Sunkook Yoo (E-mail: sunkyoo@yumc.yonsei.ac.kr)

Sunkook Yoo is an assistant professor of the Department of Medical Engineering at Yonsei University, College of Medicine. He was born and educated in Korea. He is now in charge of the Center for Emergency Medical Informatics sponsored by the Korean Ministry of Health & Welfare. His major research interests are multimedia telemedicine system, 3D image processing visualization, PACS, real-time brain wave, ECG, and EMG. Interested readers may contact the author via either e-mail addressed above or Department of Medical Engineering at Yonsei University, College of Medicine, Shinchon-dong 134, Seodaemun-gu, Seoul, Korea, 120-752.